

(21) Application No 9303011.2

(22) Date of filing 15.02.1993

(30) Priority data

(31) 04033036

(32) 20.02.1992

(33) JP

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G01S 5/14

(52) UK CL (Edition L)

H4D DMXX DPBC D23X D234 D268 D550 D561  
D565 D628

(56) Documents cited

GB 2176964 A

EP 0242099 A

WO 87/06410 A

US 5043736 A

(58) Field of search

UK CL (Edition L) H4D DLAA DLAB DPBC DSE

INT CL<sup>5</sup> G01S

Online databases: WPI, INSPEC.

(54) GPS for a vehicle

(57) Each of a plurality of base stations F in the cell 9 of a ground mobile communication system or in a mobile network control center E which controls the base stations F, is used as a fixed reference station. Errors in the positions determined by GPS reference station E, F are transmitted from the reference station to the mobile stations B obtained by GPS. If a satellite is temporarily blocked (eg by a building) the position is extrapolated on the basis of compass or gyroscope measurements and wheel speed movements.

Fig.5

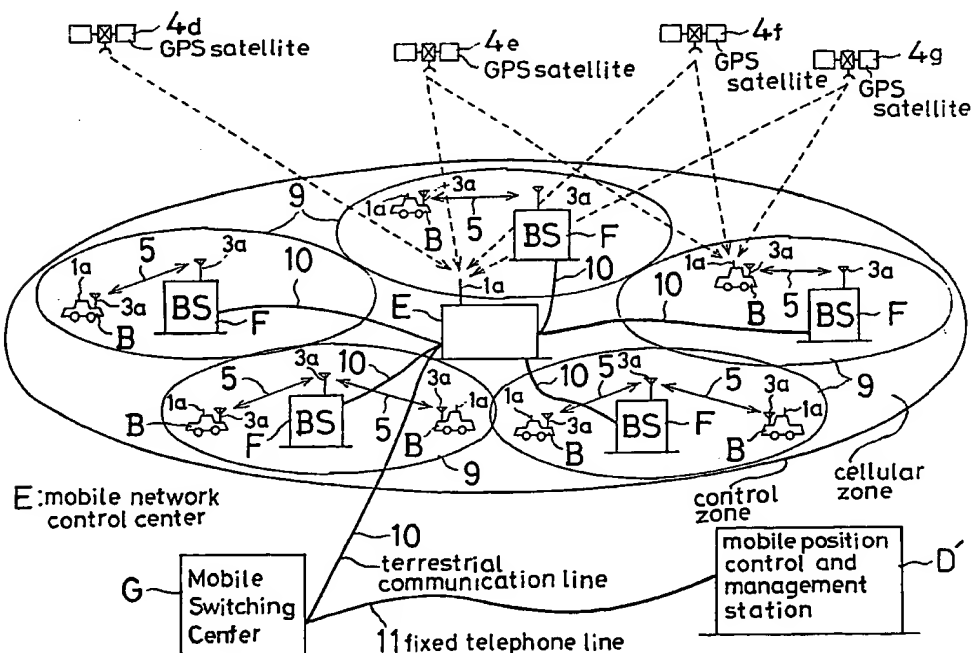


Fig.1

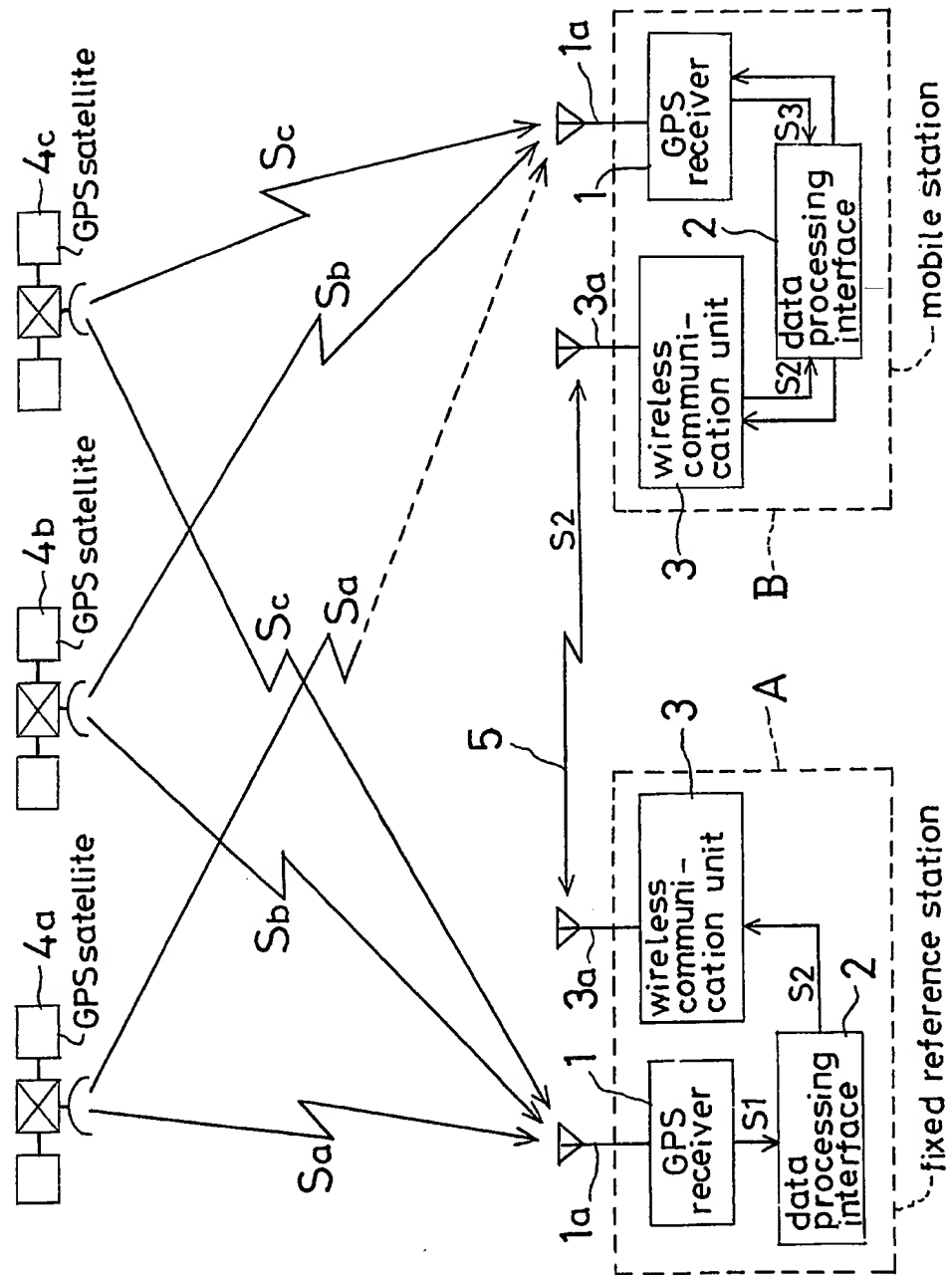


Fig.2

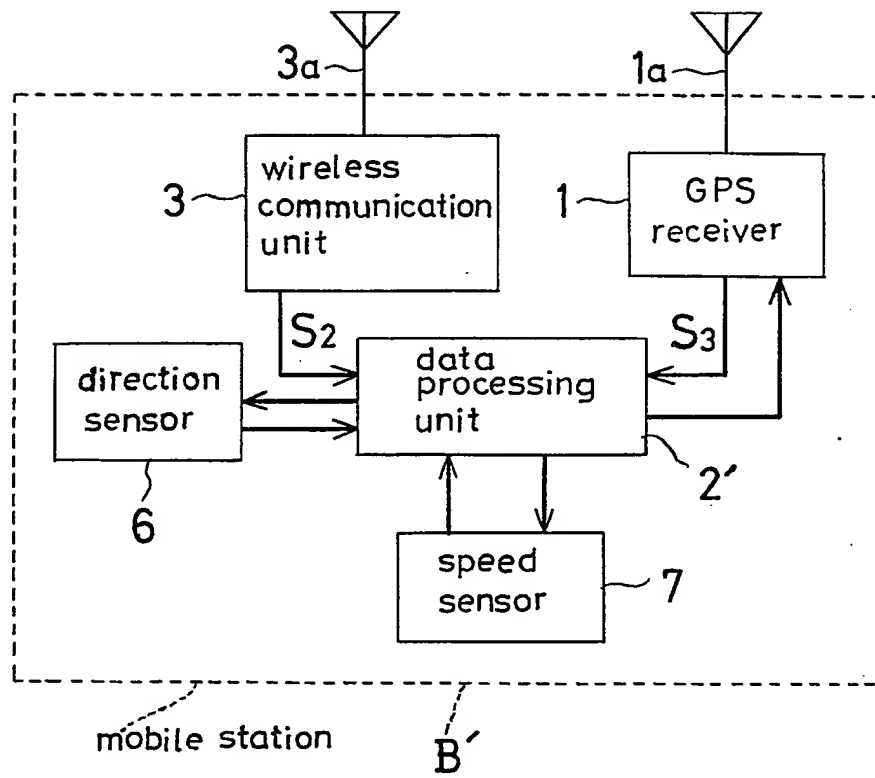


Fig.3

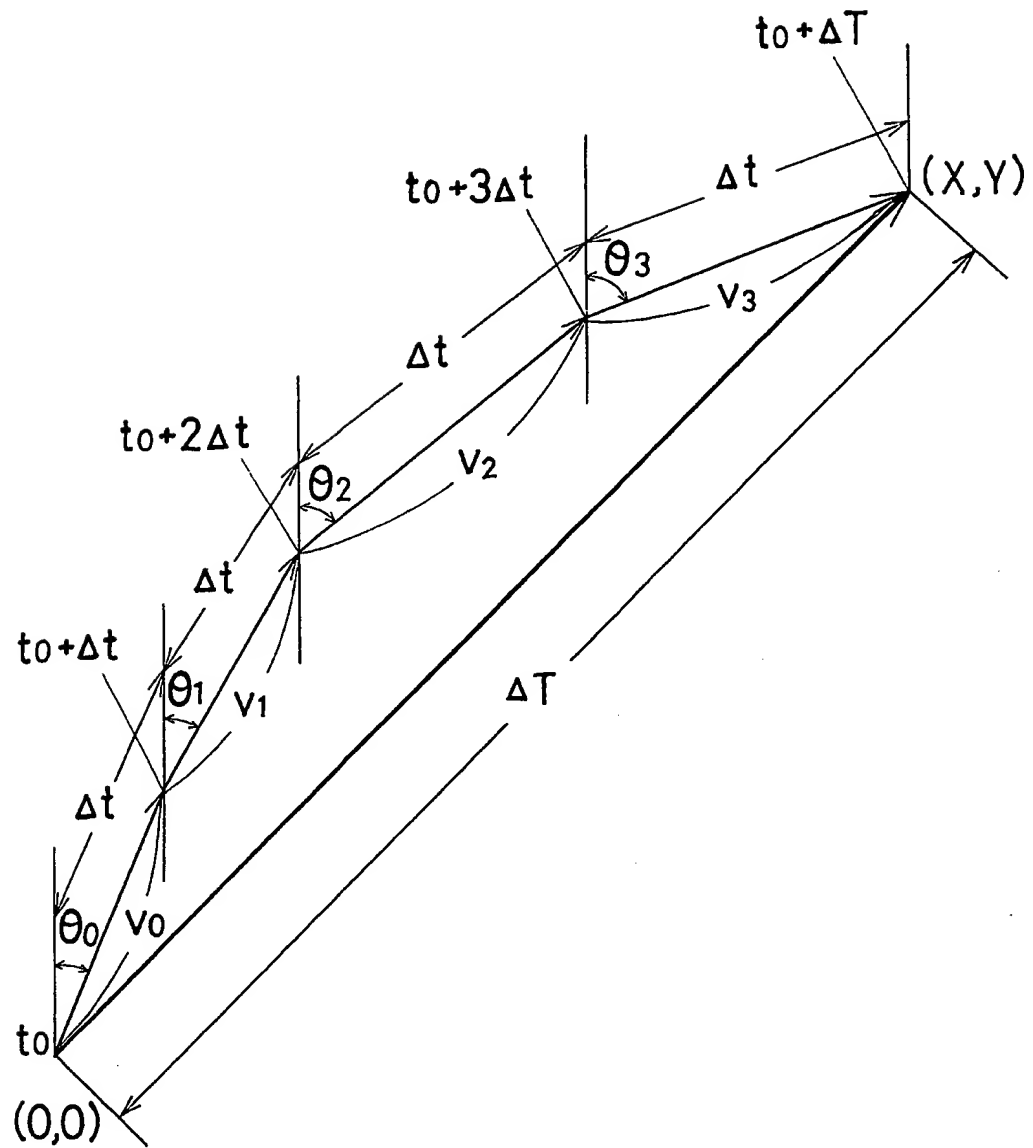


Fig.4

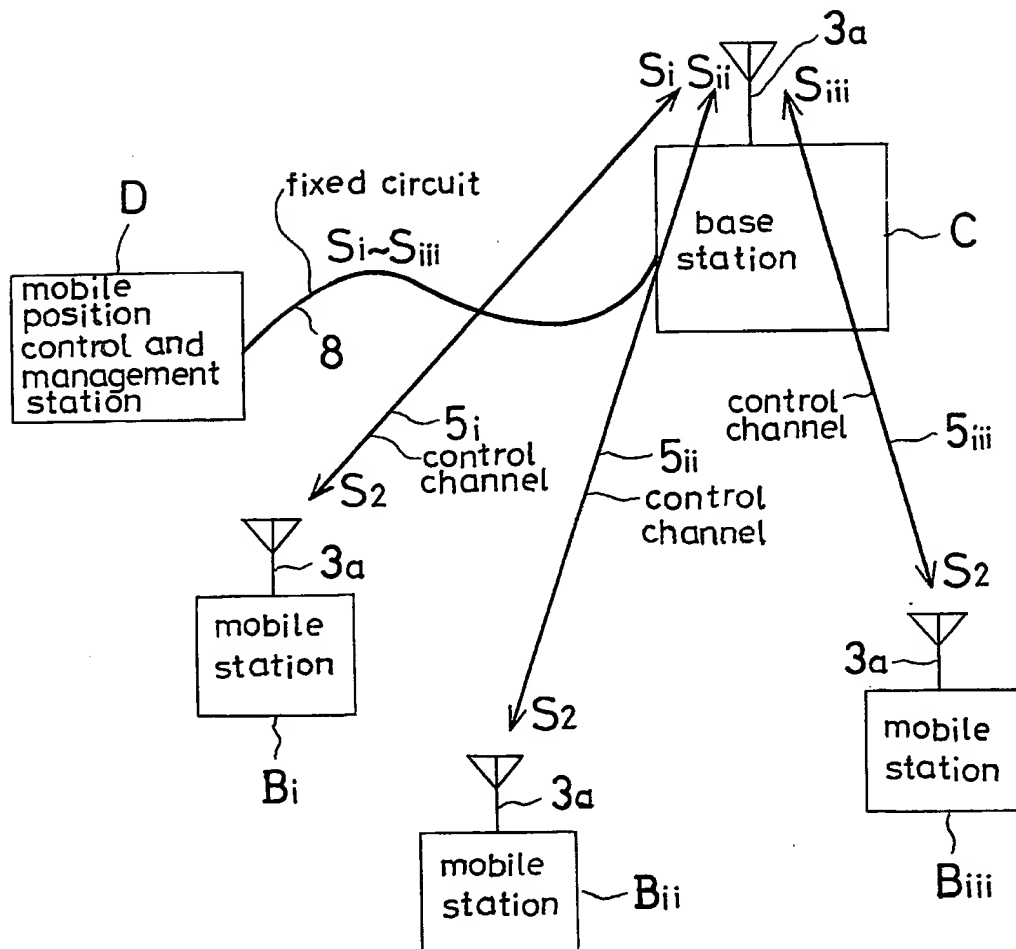
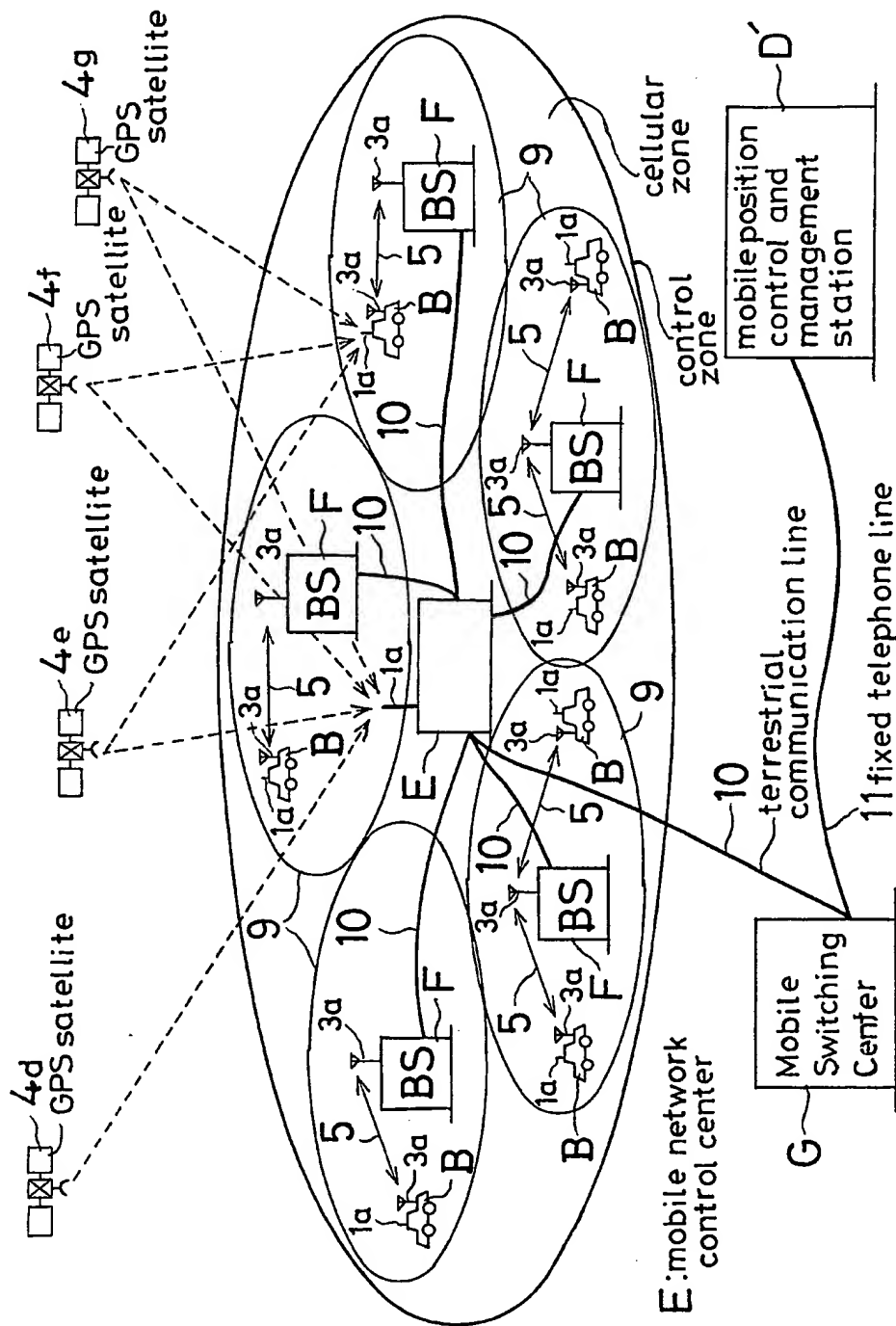


Fig.5



SPECIFICATION

Title of the invention

Method of position determination for a mobile through Global-Positioning-System satellites, and method of position reporting and management for a mobile through same

Background of the invention

The present invention relates to a method of position determination for a mobile and providing it with accurate information on the position through the use of Global-Positioning-System (which is hereinafter often referred to as GPS) satellites and a motor vehicle telephone system, a cordless telephone system, an MCA (Multi-Channel-Access) system, a paging system or the like which has such a cellular structure that each cell of the system has at least one base station. The invention also relates to a method of position reporting and management for a mobile through the use of GPS satellites and such a system described above.

In a conventional method of position determination for a

mobile through the use of GPS satellites, the distances between the mobile and the satellites are calculated in terms of the differences between the time of the reception of the signal by the mobile and the times of the transmission of the signal by the satellites, spherical surfaces whose radii are equal to the distance are drawn, and the intersection of the surfaces is found out to determine the position of the mobile. However, since there is a time deviation due to the stability of the clock at a receiver, the number of the GPS satellites necessary to determine the position within two dimensions is at least three. Even if three GPS satellites are used for the position determination, the ranging error in it can be 100 m or more because of the propagation delay due to the atmosphere or the ionosphere, the error in the orbiting of the satellites, the deviation of the clock, or the like.

To solve such a problem, differential correction method DGPS (Differential GPS) has been proposed. In the method, a GPS receiver is provided in a fixed reference station whose position is known. The difference between the measured value of the distance from a GPS satellite to the fixed reference station, and the calculated value of the distance, which is calculated on the basis of data on the orbit of the satellite and the position of the station, is sent as estimated error data from the station to a mobile station located within the radius of several hundreds of kilometers from the reference



station. In the mobile station, the propagational range error in the distance between the satellite and the mobile station, which is measured in the station, is compensated through the use of the estimated error data sent from the fixed reference station to the mobile station, and calculations are thereafter made to determine the position of the mobile station. The method is mainly used for maritime navigation. The fixed reference station is provided on the coast of a continent or an island to cover a wide service area of about 1,000 km. However, the more the mobile station nears the periphery of the service area the more the correlation between the propagation passage between the GPS satellite and the fixed reference station and that between the satellite and the mobile station decreases to lower the accuracy of the position determination for the mobile station. This is a problem. Besides, the method has other problems that a communication channel for transmitting the estimated error data from the fixed reference station to the mobile station needs to be newly provided, and it costs very much to newly install the communication channel between the fixed reference station and the mobile station.

It is also the problem that the number of GPS satellites from which the mobile station can receive the signals is limited due to the blocking of signals by a building. The blocking takes place often particularly in a crowded district

with many skyscrapers and in a mountainous district with many tall trees on both the sides of a road for the mobile station. The conventional methods of position determination through the use of at least three GPS satellites necessary for the calculation to determine the position of the mobile station can hardly be practiced in such districts.

In another such conventional method disclosed in the Japanese Patent Application Laid-open No. 63-171377, the fact that a mobile station moving on a road with buildings or trees at both the sides of the road can receive signals from GPS satellites located in front of or behind the station is utilized, and the direction of the movement of the station is found out to determine the position of the station through the use of two of the satellites. In the method, however, the mobile station is presupposed to move entirely straight, and the actual changes in the movement of the station, which are the change in the speed of the movement, the change in the direction of the movement and so forth, are not taken into consideration at all. For that reason, the method is not believed to be practicable.

Nevertheless, if a fixed reference station is constituted by the base station of an existing MCA system or by the base station or control station of an existing terrestrial based mobile communication systems of cellular structure, the radius of each zone of the former system and that of each cell of the

latter system are small as 20 to 30 km and as small as several hundreds of meters to 10 km, respectively, so that the correlation between the propagation passage between a GPS satellite and the fixed reference station and that between the satellite and a mobile station is very high. For that reason, the common component of the propagational range error in the distance between the satellite and the fixed reference station and that in the distance between the satellite and the mobile station can be almost completely compensated through the application of the differential correction method (DGPS) in order to determine the position of the mobile station always at a very high accuracy with an error of 5 to 10 m.

#### Summary of the invention

The present invention was made in order to solve the problems of the conventional methods. Accordingly, it is an object of the invention to provide a method of position determination for a mobile through the use of GPS satellites. The method is characterized in that each of base stations provided in the cells of terrestrial based mobile communication system, or a control station which controls several base stations is used as a fixed reference station; GPS receivers are provided in the mobile station;

estimated error data on the propagational range errors in the distances between the reference station and the GPS satellites, which are determined on the basis of the real distances between the reference station and the satellites and the measured distance between the reference station and the satellites, which are measured in the reference station, is transmitted from the reference station to the mobile stations through the control channels of the system; the accurate position data on the latitudes and longitudes of the positions of the mobile stations is obtained on the basis of the estimated error data transmitted from the fixed reference station and distance data on the measured distances from the satellites to the mobile stations.

A direction sensor and a speed sensor may be provided in each of the mobile stations to obtain direction data on the direction of the movement of the station through the sensors so that even if the station can receive signals from only two of the satellites and performs a curved movement, the position data on the latitude and longitude of the position of the station can be obtained on the basis of not only the estimated error data and the distance data but also the direction data through the use of the only two satellites to determine the position of the mobile station.

In the conventional DGPS method, signals from the GPS satellites are likely to be blocked by a building at the

mobile station in a crowded district or the like to lower the ranging time rate for the determination of the position of the mobile station. On the other hand, in the method provided in accordance with the present invention, each of the base stations or the control station is used as a fixed reference station, and the estimated error data obtained in the reference station is transmitted therefrom to the mobile station through the control channel of the system to heighten the ranging time rate for the determination of the position of the mobile station.

Since the method is hardly affected by the operating environment of mobile station, the position thereof can be always accurately determined in the method. Since an existing system such as the terrestrial based mobile communication system of cellular structure and an MCA system is used in the method, a new such system of high cost does not need to be provided. Accurate position information can thus be easily given to the users of the system.

It is another object of the present invention to provide a method of position reporting and management for a mobile station through the use of a plurality of GPS satellites. The method is characterized in that each of base stations provided in the cells of terrestrial based mobile communication system of a cellular structure, or a control station which controls several base stations is used as a fixed reference station;

GPS receivers are provided in the mobile stations; estimated error data on the propagational range errors in the distances between the reference station and the satellites, which are determined on the basis of the real distances between the reference station and the satellites and the measured distances between the reference station and the satellites, which are measured in the reference station, is transmitted from the reference station to the mobile stations through the control channels of the system; accurate position data on the latitudes and longitudes of the positions of the mobile stations is obtained on the basis of the estimated error data and distance data on the measured distances from the satellites to the mobile stations, if each of the mobile stations can receive signals from only two of the satellites due to the curved movement of the moving station or to the like, the position data is obtained on the basis of not only the estimated error data and the distance data, but also direction data on the direction of the movement of the mobile station, which is obtained through the use of a direction sensor and a speed sensor provided in the mobile station; the position data and the identification numbers of the mobile stations are periodically transmitted therefrom to a mobile control and management station through the reference station and the control channels; and the control and management station manages the operation of the mobile stations on the

basis of the position data and the identification numbers. The position data of the latitudes and longitudes on the positions of the mobile stations are transmitted therefrom to the fixed reference stations through the control channels of the system, and then transmitted to the mobile control and management station through a fixed communication circuit to enable the mobile control and management station to manage the operation of the mobile stations on the basis of the position data and the identification numbers of the mobile stations. Thus, accurate position information can be not only easily given to the users of the system, but also the control of the mobile stations can be easily managed.

#### Brief description of the drawings

FIG. 1 is a structural diagram of a GPS-satellite-using position determination system for practicing a GPS-satellite-using position determination method which is an embodiment of the present invention;

FIG. 2 is a structural diagram of a moving station to illustrate the case that the position of the station is accurately determined when it can receive signals from only a limited number of GPS satellites;

FIG. 3 is a chart to illustrate the principle of the

accurate determination of the position in the case;

FIG. 4 is a structural diagram of a mobile control and management system which is another embodiment of the invention; and

FIG. 5 is a structural diagram to illustrate a concrete example application of the latter method to a digital cellular telephone system.

#### Description of the preferred embodiments

Embodiments of the present invention are hereafter described in detail with reference to the drawings attached hereto.

FIG. 1 shows the structure of a GPS-satellites-using position determination system which is based on a terrestrial based mobile communication system of cellular structure and is for practicing a position determination method for a mobile station which is one of the embodiments. The position determination system includes a fixed reference station A constituted by the base station of the terrestrial based mobile communication system, a mobile station B, GPS satellites 4a, 4b and 4c, and a control channel 5 through which information is transmitted between the stations.

The fixed reference station A includes ordinary GPS



receiver 1 with an antenna 1a for receiving signals Sa, Sb and Sc from the GPS satellites 4a, 4b and 4c located in a visually unblocked range to the station, a data processing interface 2, and a fixed wireless communication unit 3 with an antenna 3a.

The interface 2 receives data S1 on the orbits of the GPS satellites 4a, 4b and 4c through the GPS receiver 1 to calculate the real distances between the fixed reference station A and the satellites, and determine the estimated propagational range errors in the measured distances between the station and the satellites, which are determined in the GPS receiver. The interface 2 converts the identification numbers of the satellites 4a, 4b and 4c and the estimated errors into data compatible with the frame format of the control channel 5 of the terrestrial based mobile communication system. For example, if integers from 1 to 32 are allocated to the identification numbers of the GPS satellites 4a, 4b, 4c, ....., and 4n and estimated propagational range error data S2 is prepared for a propagational error of  $\pm 655.32$  m with a unit interval of 0.02 m, 21-bit data needs to be provided per satellite and transmitted to the mobile station B through the wireless communication unit 3 and the control channel 5.

The mobile station B includes a GPS receiver 1 with an antenna 1a for receiving the signals Sa, Sb and Sc from the GPS satellites 4a, 4b and 4c, an interface 2 which processes

position determination data S3, and a wireless communication unit 3 with an antenna 3a. The estimated propagational range error data S2 transmitted from the fixed reference station A to the mobile station B through the control channel 5 is received and demodulated by the wireless communication unit 3, the output from which is entered into the interface 2. In the interface 2, the estimated propagational range errors in the measured distances between the mobile station and the GPS satellites, which are determined by the GPS receiver 1, are compensated by using the estimated propagational range error data S2 transmitted from the fixed reference station A to the mobile station. The calculation section of the receiver 1 provides the accurate position of the mobile station B.

Even if the GPS receiver 1 of a mobile station B' can receive only the signals Sb and Sc from the GPS satellites 4a and 4b due to a blocking at the mobile station, the position of the mobile station can be accurately determined by using the proposed method which is a modification of the former method and in which a direction sensor such as a vibratory gyroscope, an optical fiber gyroscope and a terrestrial magnetism sensor, and a speed sensor such as a vehicle speed sensor and a vehicle wheel speed sensor are used. The mobile station B' includes the GPS receiver 1 with an antenna 1a, an interface 2' which processes position determination data, a wireless communication unit 3 with an antenna 3a, the

direction sensor 6, and the speed sensor 7, as shown in FIG.

2.

When the position of the mobile station B' is to be determined thorough the use of the three GPS satellites 4a, 4b and 4c in the latter method, precise data on the direction and speed of the movement of the station, which are measured by the GPS receiver 1, is used to monitor the direction sensor 6 and the speed sensor 7 through the interface 2'.

When the position of the mobile station B' is to be determined through the use of the only two GPS satellites 4b and 4c in the method, direction data from the direction sensor 6, speed data from the speed sensor 7, distance data S3 from the GPS receiver 1, and propagational range error data S2 received by the wireless communication unit 3 from the fixed reference station A are processed by the interface 2', and position determination calculations are thereafter performed in a procedure described hereinafter. The continuous positions of the mobile station B' can thus be accurately determined.

The method is described in detail with reference to FIG. 3 from now on. If at least three GPS satellites 4a, 4b and 4c are located in a visually unblocked range to the mobile station B', the station can obtain the estimated propagational range error data S2 transmitted from the fixed reference station A to the mobile station through the control channel 5,

accurate data on the position of the station, which is data on the latitude and longitude of the position and is obtained by the GPS receiver 1 of the station, and the precise data on the direction and speed of the movement of the station, which is obtained by the GPS receiver. The accuracy of the operation of the direction sensor 6 and the speed sensor 7 is always monitored in terms of the data on the direction and speed of the movement of the station B'.

Let us suppose that when the signal  $S_a$  from the GPS satellite 4a to the mobile station B' is blocked due to the building at the station, the vector of the speed of the movement of the station, which is determined through the direction sensor 6 and the speed sensor 7 at a time point  $t_0$  at which the position of the station can be determined through the GPS receiver 1 last time, is expressed by coordinates  $(v_0 \sin \theta, v_0 \cos \theta, 0)$  in a position determination coordinate system in which the origin thereof is on the position of the station, the x-axis and y-axis of the system are on a plane extending on the origin and on the surface of the earth, the positive direction of the x-axis is eastward, the positive direction of the y-axis is northward, the z-axis of the system extends on the origin perpendicularly to the plane, and the positive direction of the z-axis is upward and which has such relationship with an earth center coordinate system that the origin of the former system at the time point is expressed by

the coordinates  $(x_0, y_0, z_0)$  of the latter system in which the origin thereof is on the center of gravity of the earth, the x-axis and y-axis of the system are on a plane containing the equator of the earth, the positive direction of the x-axis is from the origin toward the longitude of 0 degree, the positive direction of the y-axis is from the origin toward the east longitude of 90 degrees, and the positive direction of the z-axis of the system is from the origin toward the north pole. Let us also suppose that the vector of the speed of the mobile station B', which is determined through the direction sensor 6 and the speed sensor 7 at a time point  $t_0 + n \ t$ , is expressed by coordinates  $(v_n \sin n, v_n \cos n, 0)$  in the position determination coordinate system. As a result, the vector  $(X, Y, Z)$  of the direction of the movement of the mobile station B' to a place at a time point  $t_0 + \Delta t$  ( $\Delta t = M \Delta t$ ,  $n=1, 2, 3, \dots$ , and  $M$ ) to which time has elapsed since the start of the movement of the station from the original place thereof can be expressed by an equation as follows;

$$(x, y) = \sum_{j=0}^{M-1} v_j \Delta t \sin \theta_j, \sum_{j=0}^{M-1} v_j \Delta t \cos \theta_j \dots\dots (1)$$

The direction vector  $(X, Y, Z)$  is expressed as  $(\alpha, \rho, r)$  in the earth center coordinate system. The positions of the other two GPS satellites 4b and 4c and that of the mobile station B' at the time point  $t_0 + t$  are expressed as  $(a_1, b_1,$

$c_1$ ),  $(a_2, b_2, c_2)$  and  $(X, Y, Z)$ , respectively, in the earth center coordinate system. The calculations described hereinafter are then performed. The continuous position of the mobile station B' can thus be accurately determined despite the movement of the station.

The calculations are described in detail from now on. The distances between the mobile station B' and the GPS satellites 4b and 4c at the time point  $t_0 + \Delta t$ , which are removed of error factors such as propagation lag on the basis of the propagational range error data S2 transmitted from the fixed reference station A to the mobile station through the control channel 5, are expressed as follows;

$$\{(a_1 - x)^2 + (b_1 - y)^2 + (c_1 - z)^2\}^{1/2} = r_1 + r' \dots\dots (2)$$

$$\{(a_2 - x)^2 + (b_2 - y)^2 + (c_2 - z)^2\}^{1/2} = r_2 + r' \dots\dots (3)$$

In the equations (2) and (3),  $r_1$  and  $r_2$  denote the distance between the mobile station B' and the two GPS satellites 4b and 4c, which are removed of the propagational range errors on the basis of the propagational error data S2 transmitted from the fixed reference station A to the mobile station, and  $r'$  denotes an equivalent propagational range error caused by the deviation of the clock of the GPS receiver 1 of the mobile station. The equivalent propagational range error  $r'$  can be compensated by making the differences between both the sides of the equations (2) and (3) as follows;

$$\begin{aligned} & \{ (a1-x)^2 + (b1-y)^2 + (c1-z)^2 \}^{1/2} \\ & - \{ (a2-x)^2 + (b2-y)^2 + (c1-z)^2 \}^{1/2} \\ & = (r1+r') - (r2+r') = \Delta r \dots\dots (4) \end{aligned}$$

The equation (4) means a hyperboloid.

An equation meaning a straight line extending on a point  $(x0, y0, z0)$  and having a direction vector  $(\alpha, \beta, \gamma)$  is expressed as follows;

$$\frac{x-x0}{\alpha} = \frac{y-y0}{\beta} = \frac{z-z0}{\gamma} \dots\dots (5)$$

The equations (4) and (5) are solved as simultaneous equations to presume the position of the mobile station B' at the time point  $t0 + t$ .

Thus, on the basis of coordinates at a time point  $t0 + k \Delta t$  the position of the mobile station B' at a time point  $t0 + (k+1) \Delta t$  can be presumed. Therefore, the continuous positions of the mobile station B' can be accurately determined through the use of the only two satellites 4b and 4c, no matter what movement the station performs.

Since the simple interface 2, by which the position determination data S3 obtained from the GPS receiver 1 of the mobile station B or B' of the terrestrial based mobile communication system of cellular structure and the propagational range data S2 obtained from wireless communication unit 3 of the station are simultaneously processed, is provided between the receiver and the unit, the

position determination system is easily realized. The fixed reference station A, which determines the propagational range errors in the distances between the mobile station B or B' and the GPS satellites and sends the propagational error data S2 to the mobile station, is constituted by the base station C of each cell of the terrestrial based mobile communication system of cellular structure, or a control station which manages a plurality of cells of the system. The error data S2 sent out from the fixed reference station A is transmitted through a fixed circuit between the base station and the control station, or/and transmitted to the mobile station through the control channel 5 of the communication system between the base station and the mobile station. The GPS receiver 1 and the data processing interface 2 are provided in each of the base station or control station of the existing communication system and mobile station B or B' so that each of the position determination methods is realized.

Even if the mobile station B' is moving on a road with buildings or trees on both the sides of the road so that the position of the station cannot be determined in the conventional method and the station cannot receive the signal Sa from the GPS satellite 4a but the signals Sb and Sc from the other two GPS satellites 4b and 4c located in front of or behind the mobile station, the position can be accurately determined in the position determination method in which the



latter two satellites, the propagational error data S2, and the direction sensor 6 and speed sensor 7 of the mobile station are used.

FIG. 4 shows a position reporting and management system which is another of the embodiments. The system is based on a terrestrial based mobile communication system of cellular structure, and includes the mobile stations Bi, Bii and Biii each having an antenna 3a, a base station C having an antenna 3a, a mobile position control and management station D, control channel 5i, 5ii and 5iii, and a fixed circuit 8.

The fixed circuit 8 is for transmitting data between the base station C and the mobile position control and management station D. Data frames including the identification numbers of the mobile station Bi, Bii and Biii and data Si, Sii and Siii on the positions of the stations are transmitted therefrom to the base station C through the control channel 5i, 5ii and 5iii, and then transmitted from the base station to the mobile position control and management station D through the fixed circuit 8. The mobile position control and management station D manages the operation of the mobile station Bi, Bii and Biii on the basis of the identification numbers of the mobile stations and the position data Si, Sii and Siii.

The mobile position control and management method is described in detail from now on. The method is a satellite-

using method similarly to the position determination method which employs the direction sensors and the speed sensors. In the mobile position control and management method, propagational error data S2 for the mobile stations Bi, Bii and Biii is transmitted from the base station C to the mobile stations through the control channels 5i, 5ii and 5iii in the forward link, similarly to the position determination method. At the same time, the data frames including the identification numbers of the mobile stations Bi, Bii and Biii and the position data Si, Sii and Siii on the latitudes and longitudes of the positions of the mobile stations are periodically transmitted therefrom to the base station C through the control channels 5i, and 5ii and 5iii in the reverse link and then transmitted from the base station to the mobile position and control and management station D through the fixed circuit 8. The mobile position control and management station D then confirms the positions of the mobile stations Bi, Bii and Biii on the basis of the data frames to accurately and easily manage the operation of the mobile stations. Besides, various pieces of information or/and commands can be transmitted from the base station C or the mobile position control and management station D to the mobile station Bi, Bii and Biii through the control channels 5i, 5ii and 5iii.

In the methods which are the embodiments, the positions of the mobile station B, B', Bi, Bii and Biii can be

accurately determined without large expenses through the use of the GPS receivers 1 and data processing interfaces 2 of the base station C or control station of the existing terrestrial based mobile communication system of cellular structure and the mobile stations.

A concrete example of application of the mobile position control and management method to a cellular-structured digital mobile communication system is described with reference to FIG. 5 from now on. The system includes mobile stations B, a mobile position control and management station D', a mobile network control center E, cellular base stations F or BS, a mobile switching center G or MSC, cellular zones 9, terrestrial communication lines 10 for connecting the base stations and the control center to each other and connecting the control center and MSC to each other, and a fixed telephone line 11 for connecting the mobile position control and management station and the MSC to each other.

The way of practicing the mobile position control and management method to determine the positions of the motor vehicles through GPS satellites 4d, 4e, 4f and 4g is the same as that of practicing the position determination methods described above with reference to FIGS. 1, 2 and 3. The mobile network control center E for controlling the cellular zones 9 constitutes a fixed reference station of the same structure as the fixed reference station A shown in FIG. 1.

accurately determined without large expenses through the use of the GPS receivers 1 and data processing interfaces 2 of the base station C or control station of the existing terrestrial based mobile communication system of cellular structure and the mobile stations.

A concrete example of application of the mobile position control and management method to a cellular-structured digital mobile communication system is described with reference to FIG. 5 from now on. The system includes mobile stations B, a mobile position control and management station D', a mobile network control center E, cellular base stations F or BS, a mobile switching center G or MSC, cellular zones 9, terrestrial communication lines 10 for connecting the base stations and the control center to each other and connecting the control center and MSC to each other, and a fixed telephone line 11 for connecting the mobile position control and management station and the MSC to each other.

The way of practicing the mobile position control and management method to determine the positions of the motor vehicles through GPS satellites 4d, 4e, 4f and 4g is the same as that of practicing the position determination methods described above with reference to FIGS. 1, 2 and 3. The mobile network control center E for controlling the cellular zones 9 constitutes a fixed reference station of the same structure as the fixed reference station A shown in FIG. 1.

The data processing interface of the fixed reference station determines the propagational range errors in the measured distances between the station and the four GPS satellites 4d, 4e, 4f and 4g, converts the identification numbers of the satellites and the estimated errors into data compatible with the frame format of the control channels 5 of the system, and then sends the data to the cellular base stations F or BS through the terrestrial communication lines 10. The data is thereafter transmitted from the base stations F or BS to mobile station B through the wireless communication units of the base stations F or BS and the control channels 5. The mobile stations B are provided in the motor vehicles in the cellular zones 9. The mobile stations B have the same structure as those B shown in FIG. 1. The propagational range errors in the measured distance between each mobile station B and the GPS satellites, which are determined by the GPS receiver of the station, are compensated in the station on the basis of the estimated error data transmitted from the base station F or BS to the mobile station through the control channel 5, so that more accurate distance data is created.

Data frames including the identification numbers of the mobile stations B and position data on the latitudes and longitudes of the positions of the stations are transmitted therefrom to the base stations F or BS through the control channels 5 in the reverse link, and then transmitted from the

base stations to the control station E. The position data is transmitted from the control station E to the G or MSC through the terrestrial communication line 10, and then transmitted from the latter station to the mobile position control and management station D' through the fixed telephone line 11. The station D' confirms the positions of the mobile stations B on the basis of the position data to accurately and easily manage the operation of the mobile stations. Besides, various pieces of information sent to the mobile position and management station D' from a traffic information center or the like connected to the station through another fixed telephone line but not shown in FIG. 5. and commands can be transmitted from the station to the mobile stations B through the former fixed telephone line 11 and the terrestrial communication lines 10.

The present invention is not confined to the embodiments and the modification, but may be embodied or practiced in other various ways without departing from the spirit or essential character of the invention. For example, instead of terrestrial based mobile communication system, an MCA system may be used.

CLAIMS

1. A method for determining the positions of mobile stations by use of a plurality of Global-Positioning-System satellites, wherein each of a plurality of base stations provided in the cells of a terrestrial based mobile communication system of cellular structure, or a control station which controls several base stations, is used as a fixed reference station; estimated error data relating to the propagational range errors in the distances between said reference station and said satellites, determined on the basis of the real distances between said reference station and said satellites and the measured distances between said reference station and said satellites, which are measured in said reference station, is transmitted from said reference station to said mobile stations by way of the control channels of said communication system; and position data relating to latitudes and longitudes of the positions of said mobile stations is accurately obtained on the basis of said estimated error data and distance data relating to the measured distances between said satellites and said mobile stations.

2. A method according to the claim 1, wherein a direction sensor and a speed sensor are provided in each of said mobile stations to obtain direction data relating to the direction of movement of said mobile stations by use of said sensors, so that, even if one of said mobile stations can receive signals from only two of said

CLAIMS

1. A method for determining the positions of mobile stations by use of a plurality of Global-Positioning-System satellites, wherein each of a plurality of base stations provided in the cells of a terrestrial based mobile communication system of cellular structure, or a control station which controls several base stations, is used as a fixed reference station; estimated error data relating to the propagational range errors in the distances between said reference station and said satellites, determined on the basis of the real distances between said reference station and said satellites and the measured distances between said reference station and said satellites, which are measured in said reference station, is transmitted from said reference station to said mobile stations by way of the control channels of said communication system; and position data relating to latitudes and longitudes of the positions of said mobile stations is accurately obtained on the basis of said estimated error data and distance data relating to the measured distances between said satellites and said mobile stations.

2. A method according to the claim 1, wherein a direction sensor and a speed sensor are provided in each of said mobile stations to obtain direction data relating to the direction of movement of said mobile stations by use of said sensors, so that, even if one of said mobile stations can receive signals from only two of said



satellites due to a curved movement of said mobile station, the position data relating to the latitude and longitude of the position of said mobile station can be obtained on the basis of not only said estimated error  
5 data and said distance data but also said direction data by use of said only two satellites to determine said position.

3. A method of mobile position control and management by use of a plurality of Global-Positioning  
10 System satellites, wherein each of a plurality of base stations provided in the cells of a terrestrial based mobile communication system of cellular structure, or a control station which controls several base stations, is used as a fixed reference station; estimated error data  
15 relating to the propagational range errors in the distances between said reference station and said satellites, determined on the basis of the real distances between said reference station and said satellites and the measured distances between said reference station and said  
20 satellites, is transmitted from said reference station to a plurality of mobile stations by way of the control channels of said communication system; position data relating to the latitudes and longitudes of the positions of said mobile stations is accurately obtained on the  
25 basis of said estimated error data and distance data relating to the measured distances between said satellites and said mobile stations, and, if one of said mobile stations can receive signals from only two of said

satellites due to a curved movement of said mobile station, said position data is obtained on the basis of not only said estimated error data and said distance data but also direction data relating to the direction of movement of said mobile station, which is obtained by use of a direction sensor and a speed sensor which are provided in said mobile station; said position data and the identification numbers of said mobile stations are periodically transmitted therefrom to a mobile position control and management station by way of said reference station and said channels; and said control and management station controls operation on the basis of said position data and said identification numbers.

4. A method of determining the positions of mobile stations by use of a plurality of Global-Positioning-System satellites, the method being substantially as hereinbefore described with reference to one or more of the figures of the accompanying drawings.

5. A method of mobile position control and management by use of a plurality of Global-Positioning-System satellites, the method being substantially as hereinbefore described with reference to one or more of the figures of the accompanying drawings.

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**Patents Act 1977**  
**Examiner's report to the Comptroller under**  
**Section 17 (The Search Report)**

Application number

GB 9303011.2

**Relevant Technical fields**

(i) UK Cl (Edition L ) H4D (DLAA, DLAB, DPBC, DSE)

(ii) Int Cl (Edition 5 ) G01S

**Databases (see over)**

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI, INSPEC

**Search Examiner**

DR E PLUMMER

**Date of Search**

17 MARCH 1993

Documents considered relevant following a search in respect of claims ALL

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	GB 2176964 A (STC)	
A	EP 0242099 A (ADVANCED STRATEGICS)	
A	WO 87/06410 A (MAGNAVOX)	
A	US 5043736 (CAE-LINK)	

Category	Identity of document and relevant passages	Relevant to claim(s)

#### Categories of documents

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Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

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